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ABSTRACT

Two experiments examined proofreading errors to test whether reading is mediated by a phonological recoding stage. In the first experiment, 162 undergraduates circled the misspelled words in a text as the experimenter read the passage aloud. In the second experiment, 165 undergraduates corrected misspellings as they read the same passage silently, and then completed a spelling test of the misspelled words and a three-question comprehension test. In both experiments, half the misspellings were phonologically consistent ("brane" for "brain") and half were phonlogically inconsistent ("brone" for "brain"). Subjects in both experiments failed to detect significantly more phonologically consistent misspellings than phonologically inconsistent misspellings. The second experiment's comprehension test, moreover, demonstrated that good performance in the proofreading task is not achieved at the expense of comprehension. The study concludes that reading is, in fact, mediated by a phonological recoding stage and that this stage takes precedence over other stages that are used to extract meaning from written language. (RL)

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Phonological Interference in Proofreading: Evidence for the Primacy of Phonological Recoding in Lexical Access

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The blotches of ink on paper that we know as words are not inherently possessed of any meaning. Before they can become associated with their meanings, they must first be converted into some form which allows them to be mapped onto entries in the mental lexicon. The concern of this paper and the research reported herein is just what form or forms words assume en route from printed page to meaning. Specifically, we are concerned with whether or not words undergo a phonological recoding prior to lexical access.

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The concept of phonological recoding in silent reading is a venerable one which was studied as long ago as the turn of the century. In that era, Huey (1908) wrote

> It is perfectly certain that the inner hearing or pronunciation, or both, of what is read, is a constituent part of the reading of by far the most part of people, as they ordinarily and actually read. The evidence is cumulative from many sources, and...there is no doubt as to the fact. (Pp. 117-118)

And though in 1977 there is considerable "doubt as to the fact," phonological recoding still has a certain intuitive appeal.

Consider the child faced with the task of learning to read. He has already learned to comprehend spoken language and hence, has a fully functioning phonological system for accessing his lexicon. One could argue that for the child there is a certain cognitive economy to his making use of this system when reading. He needs merely to learn the rules for assigning printed words to their phonological representations, and he can quickly learn to comprehend written language. His alternative is the arduous task of learning tens of thousands of new, arbitrary associations between printed words and their meanings.

One could argue that deaf persons can learn to read, and yet they make use of no such phonological system, (as is also the case for readers of logographic languages such as Chinese), but surely theirs is Hobson's choice: they have no system of rules by which graphemes are systematically related to phonetic aspects of the language, so it should not be surprising that they do not use any.

But beyond these conceptual arguments, there exists a corpus of recent empirical evidence in support of phonological recoding. Rubenstein, Lewis, and Rubenstein (1971) reported that subjects faced with a word/nonword decision are slower to reject nonsense words which are homophonous with some English word (e.g., "deap"), than nonsense words which are not homophonous with any English word. These data suggest that the nonhomophonous nonwords can be rejected on phonological grounds alone while the homophonous nonwords require further processing (for example, a post-access spelling check) before they can be rejected.

This interpretation was confirmed in experiments reported by Bias and McCusker (1976) who replicated the Rubenstein et al. (1971) experiment, but used exposure durations near the subject's threshold for discrimination (usually around 40 msec when followed by visual noise mask). In this experiment, the exceedingly brief presentation of each item presumably compels the subject to use his most expeditious means of word recognition, and under these conditions, the presence of phonological recoding was still apparent.

Nevertheless, the phonological recoding model is not without its opponents. Smith (1971), Kolers (1970), and others have argued in favor of various direct access models whereby a reader accesses his lexicon directly from the print without any sort of phonological mediation. The most persuasive evidence in favor of this notion comes from Kleiman (1975). He presented subjects with pairs of words and asked them to make one of three judgments: "Does this pair rhyme?", "Are these words spelled alike after the first letter?", or "Are these words synonyms?". He found that a shadowing task interfered greatly with the rhyme judgment as one would expect it to in any task requiring phono-

logical recoding. Conversely, shadowing caused relatively little interference with the spelling judgment, which presumably required little recoding. Finally, shadowing caused as much interference with the synonomy judgment as it had with the spelling judgment, leading Kleiman to conclude that recoding is not necessary for lexical access.

Thus, while there is much evidence which demonstrates the existence of phonological recoding, there is also good evidence which suggests the possibility of going directly from print to meaning. However, all the recent evidence, on both sides of the issue, comes from experiments using materials with low ecological validity in highly artificial tasks. The use of nonwords, isolated single words, and isolated pairs and groups of words in tasks like word/nonword judgments, meaningfulness judgments, or synonomy judgments while shadowing has created a corpus of discordant results and contradictory conclusions. What is needed then, is a task that more closely resembles reading where subjects are engaged in the perusal of ongoing text and are seeking to extract its meaning.

To this end, we sought to study the behavior of the proofreader, seeking to find spelling errors in text while reading along. Does he make use of phonological recoding in his search for misspellings? Specifically, will he show any difference in his ability to detect misspellings which are phonologically consistent with the intended word (e.g., "brane" for "brain") as compared with those which are phonologically inconsistent (e.g., brone)? If the proofreader is using phonological recoding one would predict that the misspellings of the former sort would go undetected more often than would the latter.

To test this prediction Experiment 1 was conducted.

Experiment 1

Method

Subjects

One hundred and sixty-two undergraduates at the University of Texas at Austin served voluntarily as subjects. All were students in an introductory psychology course.

Procedure

While an experimenter read aloud, subjects read a 650-word passage taken from "Psychology Today." They were instructed to circle any misspelled words they might find in the passage. The passage contained 24 misspellings, 12 phonologically consistent with the intended word (e.g., "first" misspelled "furst"), and 12 phonologically inconsistent, (e.g., "first" misspelled "farst"). We used two versions of the passage such that a word that was misspelled in one way on the first version was misspelled the other way on the second version, and approximately half of the subjects proofread each version. We created our misspellings by replacing one letter in a word with another letter of the same shape--ascenders with ascenders, descenders with descenders, etc. In addition, within each version, misspelled items were yoked such that for any item, the two different letter replacements required to make the two types of nonwords appeared in both versions. Thus, on the first version "first" was misspelled "furst" and "birth" was misspelled "barth," while on the second version "first" was misspelled "farst" and "birth" was misspelled "burth."

Results

On the average, the subjects failed to detect 2.08 phonologically consistent misspellings and 1.30 phonologically inconsistent misspellings. The difference is highly significant, $F(1,160)=36.41$, $p < .0001$. There is no significant difference between the number of errors on the first version (1.53) and the number of errors on the second version (1.83), $F(1,160)=1.81$, $p=.1799$. The effect of the individual items which is manifest in the interaction between the type of error and the version is also significant, $F(1,160)=7.971$, $p=.0054$.

Discussion

The results strongly suggest that our proofreaders made use of phonology even though it was not to their advantage to do so, since its use worsened their performance. Nevertheless, the astute skeptic might argue that in our proofreading task where one proofreads while hearing the passage read aloud, phonology must certainly play a role, but only because of the inescapable voice of the experimenter. It is possible that we forced our subjects into using phonological recoding by having the experimenter read the passage aloud. Also, one might argue that the differences we found were due solely to the subjects' not knowing how to correctly spell the misspelled words. Certainly, a subject who did not know how to spell "treatment" would be more likely to know that "trectment" is a misspelling than that "treetment" is. Finally, it is not clear how much proofreading resembles actual reading. There is no way to know from these data if our proofreaders were extracting any of the meaning of the passage. In fact, the act of proofreading might seriously hamper one's ability to comprehend. So, in an

attempt to answer these objections and to replicate our previous result, we reran our experiment with the following modifications.

Experiment 2

Method

A new group of 165 subjects read the same passages, this time in silence. They were given three minutes to read the passages, and they were paced by an experimenter who notified them when 3/4, 1/2, and 1/4 of the time remained. In addition, some of the target words that were potentially difficult to spell were replaced or removed. Finally, a spelling test on all the words misspelled in the passage and a brief (three question) comprehension test were administered to all subjects after the proofreading session.

Results

Of the 165 subjects, 5 failed to spell all of the 22 items correctly and their data were excluded from the analysis. For the remaining 160 subjects, the average number of undetected phonologically consistent misspellings was 2.92, while the average number of undetected phonologically inconsistent misspellings was 2.09. As in Experiment 1, the difference is highly significant, $F(1,156)=30.02$, $p < .001$, and there was no significant difference between the two versions, $F(1, 156)=1.14$, $p=.286$. On the comprehension test, seven of the subjects answered none of the questions correctly; 20 answered only one; 65 answered two; and 68 answered three. Subjects were divided into two groups based on how they performed on the comprehension

test such that subjects who correctly answered all of the questions were designated high comprehenders, while subjects who had missed one, two, or three of the questions were designated low comprehenders. This demarcation led to the formation of two groups of N=68 and N=92, respectively. The high comprehenders failed to detect an average of 3.23 phonologically consistent misspellings and 2.54 phonologically inconsistent ones, while the low comprehenders failed to detect an average of 2.61 phonologically consistent misspellings and 1.63 phonologically inconsistent ones. The difference between the good and bad comprehenders is significant $F(1,156)=6.29$, $p=.013$, while the interaction of comprehension and type of undetected misspelling is not, $F(1,156)=.91$, $p=.343$. Finally, none of the other interactions approaches significance.

Discussion

This pattern of results in Experiment 2 is nearly identical to that of Experiment 1, and once again the subjects' reliance on phonological recoding manifests itself, this time in silent proofreading. Moreover, the high comprehenders were also the better proofreaders, suggesting that good performance on the proofreading task was not achieved at the expense of comprehension.

General Discussion

Given these data, as well as all of the other empirical evidence and conceptual arguments in support of phonological recoding, we are ready to conclude that the processing of print into meaning is mediated by a phonological stage. Furthermore, we believe that no model of lexical access that excludes a phonological route is acceptable. However,

we are still unable, especially in light of Kleiman's data, to claim that it is the sole route. Certainly some sort of parallel access model--whereby direct, phonological, and perhaps other forms of access proceed simultaneously--is possible and even probable. Nevertheless, we would still maintain that phonological recoding is the primary route of lexical access.

To support this contention we are able to adduce two facts, one regarding the unavoidability of using phonological recoding and another pertaining to its efficiency. First, phonology intrudes upon tasks where it functions solely to the detriment of the subject. Such was the case in Experiments 1 and 2. Another instance of this is an experiment reported by Gough and Cosky (1977), using the Stroop color word technique. They had subjects name the color of ink that letter strings were printed in. Among the types of strings presented were names of colors (always different from the color of ink), ordinary (non-color) words, nonwords homophonous with color words (e.g., bloo, wredd), and other pronounceable nonwords. They found that the naming of the color of ink of the strings was equally impaired for the nonwords homophonous with color names and for the color names themselves, while the nonwords that were pronounceable but not homophonous with color words were no more difficult than the ordinary words. "That is, nonwords which sound like color words produce a Stroop effect as great as those words themselves." (Gough and Cosky, 1977, p. 279). Thus, phonological recoding intrudes into these two tasks (i.e., proofreading and color naming) even when it can only harm the subjects' performance. Moreover, it appears that it is beyond the subjects'

power to avoid its use, especially in the Stroop task, where subjects often report that they try to avoid its interfering effect but are unable to do so.

The second fact which indicates that phonological recoding is the primary route of lexical access is that reported by Bias and McCusker (1976). Recall that they had subjects view homophonous nonwords, nonhomophonous nonwords, and words, at exposure durations near threshold. In their experiment subjects viewed blocks of 40 items, 20 words and 20 nonwords. Only one type of nonword was used in any given block, and all of the words were used twice in the course of the experiment, once with each type of nonword. They found that when presented in blocks with the same words, the homophonous nonwords were more difficult to identify as nonwords than were the nonhomophonous nonwords. Here, where subjects were forced to use their fastest and most efficient strategy, the effects of phonology are readily apparent. Thus, phonological recoding is manifest when subjects are able to do only the bare minimum amount of processing and presumably opt for the easiest way to accomplish the task.

Therefore, given that phonology intrudes into both proofreading and the Stroop task and that it is manifest at near threshold performance, we conclude that it is not only an unavoidable route from print to meaning, but that it is also the swiftest and most efficient route.

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